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G. P. Callas
D. G. Denery
G. H. Hardy
B. F. Nedell, Ames Research Center, Moffett Field, California

National Aeronautics and
Space Administration

Ames Research Center
Moffett Field, California 94035

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FLIGHT EVALUATION RESULTS FROM THE GENERAL-AVIATION ADVANCED AVIONICS SYSTEM PROGRAM

G. P. Callas,* D. G. Denery,† G. H. Hardy,‡ and B. F. Nedell*

Ames Research Center
Moffett Field, California 94035

Abstract

NASA Ames Research Center has recently tested a demonstration advanced avionics system (DAAS) for general-aviation aircraft. The objective was to provide information required for the design of reliable, low-cost, advanced avionic systems which would make general-aviation operations safer and more practicable. Guest pilots flew a DAAS-equipped NASA Cessna 402-B aircraft to evaluate the usefulness of data busing, distributed microprocessors, and shared electronic displays, and to provide data on the DAAS pilot/system interface for the design of future integrated avionics systems. Evaluation results indicate that the DAAS hardware and functional capability met the program objective. Most of the pilots felt that the DAAS was representative of the way avionics systems will evolve and felt the added capability would improve the safety and practicability of general-aviation operations. This paper presents the flight-evaluation results compiled from questionnaires, summarizes the results of the debriefings, and presents the general conclusions of the flight evaluation.

Introduction

The rapid growth of civil aviation over the past two decades has placed increasing demands on the national airspace system, resulting in new restrictive regulations, complicated operating procedures, and more avionics. These new demands make it increasingly difficult for the general-aviation pilot to operate safely and economically in high-density areas during adverse weather or under instrument-flight rules (IFR). During this same period the general-aviation industry has been very aggressive in applying new technologies and developing new systems to meet the demands of the national airspace system. The addition of these new systems to the already crowded instrument panel presents new problems. The solution clearly requires a departure from traditional avionics toward more integration, incorporating shared displays and controls. However, the integration itself may create new problems for the general-aviation pilot.

To investigate these problems, Ames Research Center initiated a program in 1975 to provide the critical information required for the design of integrated avionics suitable for general aviation and to provide improved functional capability to enhance safety and reduce pilot workload for single-pilot IFR flight. In 1978 a contract was awarded to Honeywell Inc. and King Radio Corp. for the design and analysis of a projected advanced avionics system (PAAS) concept suitable for general aviation and for the fabrication and installation of a demonstration advanced avionics system (DAAS) capable of demonstrating the most critical elements of PAAS, into a NASA-owned Cessna 402B twin-engine general-aviation aircraft. DAAS was designed to evaluate the feasibility of developing an integrated system that would provide the pilot with an improved capability and be modular, reliable, and easy to maintain. The DAAS acceptance tests were conducted at Olathe, Kansas, in June 1981, and an operational evaluation by more than 100 pilots and observers, representing all segments of the general-aviation community, was completed in May 1982.

An overview of the program with a summary of the results that led to the DAAS specifications is contained in Ref. 1. A preliminary functional description of DAAS is provided in Ref. 2, and a detailed description of both the PAAS and DAAS is provided in Refs. 3 and 4. Preliminary results of the flight test are contained in Ref. 5, and the program summary is described in Ref. 6. The purpose of this paper is to present the flight evaluation results compiled from the flight evaluation questionnaires, summarize the results of the debriefings, and present the generalized conclusions of the flight evaluation from the point of view of a pilot as an untrained operator of an advanced interactive avionics system.

DAAS Pilot/System Interface

Major hardware elements of the DAAS include a microcomputer complex, an integrated-data-control center, an electronic horizontal situation indicator, and a radio adaptor unit. All processing and display resources are interconnected by an IEEE-488 bus to enhance the overall system effectiveness, reliability, modularity, and maintainability. To achieve these features, DAAS was designed to have a reconfiguration capability in the event of certain failures. A more complete description of this capability is contained in Refs. 3 and 4.

The DAAS was designed to provide a high degree of operational flexibility and capability while minimizing complexity. The primary interface between DAAS and the pilot is achieved through an electronic horizontal situation indicator (EHSI), an integrated-data-control center (IDCC), an assortment of function and mode-select buttons, and a two-axis slew control (Fig. 1). Specific design guidelines included 1) identical electronic display formats for the various DAAS functions, 2) direct access (as opposed to

*Aerospace Engineer.
†Chief, Aircraft Guidance and Navigation Branch.
‡Research Pilot/Engineer.

sequential access) to all of the system capabilities and functions, 3) the minimal requirement for the pilot to change the displayed information during a normal flight, and 4) a system design making the DAAS an information source rather than a decisionmaker.

To demonstrate these features, DAAS was designed to include 1) an automated guidance and navigation capability, using VOR/DME navigational facilities; 2) standard flight control with navigation coupling; 3) a flight-status function; 4) computer-assisted and automated handbook computations, such as weight, balance, and performance; 5) a monitoring and warning system that alerts the pilot about aircraft mismanagement and engine anomalies; 6) storage of normal and emergency checklists and operational limitations; 7) a data-link capability using the discrete address beacon system (DABS) or Mode S transponder (the FAA-proposed replacement for the ATCRBS transponder); 8) maintenance; and 9) a simulation mode for pilot training and familiarization. These capabilities are described in greater detail below.

Functional Capabilities

Guidance and Navigation. The DAAS provides for standard ILS/localizer and VOR/DME navigation, and area and vertical navigation with respect to an arbitrary waypoint and with respect to a predefined flightpath specified by a sequence of linked or connected waypoints. The DAAS allows a combination of up to ten of any of the above waypoints to be stored in nonvolatile memory. In addition, the frequency, station identifier, magnetic variation, elevation, and latitude and longitude positions for up to ten navigation stations can be stored. The system is mechanized so that these navigation facility data can be used to reduce the data entry required for defining specific waypoints. Waypoints (WP) are defined by manual entry of radial and distance information with respect to one of the defined navigational facilities or by automatically using one of the three map edit features: WP present position, WP generate, or cursor slew control. The first feature allows the pilot to define a WP at his present position; the radial and distance information is automatically entered on the EHSI. The second feature automatically defines a straight-line sequence of WPs equally spaced between a "Start WP" and an "End WP." Each generated WP is referenced to the closest navigation facility stored in the system. With the third feature, the pilot can graphically define a WP by using the slew control to position a cursor on the EHSI to correspond with the desired location on the map. The radial and distance information corresponding to the cursor position is automatically copied onto the WP data page.

The area and vertical-navigation capability is representative of current-generation systems. The measurements from a single VOR/DME are blended with true airspeed, heading, and barometric altitude to provide an improved signal. In addition, the VOR and DME Morse-code identifiers are decoded and correlated with the desired station identifier for positive station identification. The navigation outputs include ground speed, ground track, winds, and aircraft position with respect to the selected flightpath.

Flight Control. The flight-director/autopilot is a digital implementation of the King KFC 200 autopilot, modified to make it compatible with the DAAS navigation system. The autopilot modes include altitude hold, altitude arm, vertical navigation, yaw damper, heading select, navigation arm, navigation coupled, approach arm, and approach coupled. If the autopilot is coupled to the area-navigation function, the autopilot provides (upon pilot request) automatic transitioning between WP inbound and outbound courses.

Flight Status. A Greenwich Mean Time (GMT) clock and fuel totalizer function is used with the area-navigation capability just described to provide the pilot with a complete assessment of his flight status. Included are continuous computations of 1) GMT time, ground speed, winds, power setting, and fuel remaining; 2) the distance and time required to reach each WP in a predefined sequence of WPs; and 3) the estimated time of arrival and fuel remaining at each of these waypoints.

Computer-Assisted Handbook Computations. The DAAS provides a capability for assisting the pilot in rapid computations of weight and balance, takeoff performance, and cruise performance. Inputs to the weight and balance calculation, such as fuel load and passenger weight, are entered manually through the IDCC. The DAAS then computes the center of gravity and gross weight and alerts the pilot if the computed values are out of the allowable range. Inputs to the performance calculations can be performed by manual data entry or automatic entry of sensor data such as manifold pressure (MAP), engine rpm, outside air temperature (OAT), barometric altitude, winds, and aircraft weight (using the fuel-totalizer function) available in the DAAS at the time of the computation. The DAAS then provides estimates of the fuel burn rate, mileage per unit of fuel burned, percent power, true airspeed, and ground speed.

Monitoring and Warning. A significant contribution of an integrated avionics system is its ability to correlate the measurements from different sources and alert the pilot to abnormal or unsafe conditions. To demonstrate this concept the DAAS includes an engine-monitoring function, an aircraft-configuration-monitoring function, and a ground-proximity warning function.

The engine-monitoring function provides continuous monitoring of manifold pressure and engine rpm. The aircraft-configuration-monitoring system continually monitors the position of the doors, landing gear, cowl flaps, wing flaps, auxiliary fuel pumps, and trim as a function of aircraft state. In both cases the pilot is alerted to out-of-tolerance conditions.

The ground-proximity warning function is based on Mode 1, defined in ARINC Specification 594-1 and alerts the pilot to excessive rates of descent with respect to the terrain.

Normal and Emergency Checklists and Operational Limitations. The normal and emergency checklist and operational limitations are stored in the DAAS so that the pilot can quickly and easily refer to them.

Data Link. ATC communications, weather reporting, or weather information at destination can be communicated to the pilot via the transponder data link and displayed on the IDCC. To introduce the demonstration pilots to the capabilities of DABS, certain of its features are simulated in the DAAS.

Maintenance Assistance. The DAAS includes built-in test (BIT) to assist maintenance and fault isolation. The BIT is designed to facilitate the demonstration of advanced avionics testing concepts for general-aviation maintenance. The DAAS also includes an automatic functional-test/fault-localization, available at

powerup or when commanded by the operator, that identifies failed line-replacement units, and an interactive functional test capability that allows the testing of devices when operator actions or observations are necessary to complete a test.

Simulation Mode. By selecting the simulation mode, the DAAS can be used as a simulator on the ground for pilot training. The pilot controls the simulated aircraft through the autopilot mode-select panel. All DAAS displays, controls, and functions can be demonstrated in the ground simulation mode.

Guest-Pilot Evaluation Program

The primary purpose of the guest-pilot evaluation program was to expose the various segments of the general-aviation community to the DAAS, solicit their comments, and gain insight into the improvements and problems associated with this type of integration. Representatives from all segments of the general-aviation industry participated in the flight evaluations, including airframe companies, avionics companies, fixed-base operators, universities, magazine editors, and government organizations including NASA, the FAA, and DOD. A total of 64 evaluation flights were conducted in which 117 pilots and observers participated. A typical flight evaluation included: a 2- to 3-hr review of the DAAS, which covered the program objectives, the system architecture, the pilot/system interface, and the planned flight scenario; a 1-hr ground simulation in the DAAS aircraft to exercise the DAAS functions and review the flight scenario; a 75-min flight; and a 1-hr post-flight debriefing. At the conclusion of the debriefing the subjects were given a questionnaire that was to be completed at a later time and returned. The results presented in this paper are taken from the 59 questionnaires that were returned and from the 64 debriefings that were taped after the flights.

The DAAS flight scenario was designed to demonstrate most of the key DAAS flight functions. Those functions not used in flight, such as the built-in-test function or the discreet address beacon system function, were demonstrated using the ground simulation mode.

A description of the flight scenario and the functions performed by the evaluation pilot is useful in understanding the questionnaire responses. A typical flight is shown in Fig. 2. The flight originated at Moffett Field at the south end of the San Francisco Bay and proceeded to Salinas, about 12 miles inland from Monterey Bay. The standard instrument departure was followed leaving Moffett Field, and the standard ILS approach was followed at Salinas down to the minimum decision altitude where a missed approach was initiated for the return to Moffett Field. Waypoints were located at key intersections en route to define the flight plan and to aid in the demonstration of the various DAAS functions. Waypoints 6 and 8 are not shown on the map. Waypoint 6 was defined as the Salinas ILS, and was coincident with WP5; it was used for the ILS approach into Salinas. Waypoint 8 was left blank in the flight plan but was generated during the flight to demonstrate the waypoint-generate feature incorporated in DAAS. The long leg between WP2 and WP3 was used to demonstrate the flight-planning and performance functions, and the leg between WP3 and WP4 was used to set up the intercept to the Salinas ILS to demonstrate the EHSI display in the ILS mode and the autopilot/flight director performance during the missed approach at Salinas.

After the missed approach at Salinas, and before reaching the missed approach point WP7, two additional map-edit features were demonstrated. The first was the "waypoint present position" feature, which relocated WP7 under the aircraft, and the second was the "WP generate" feature, which inserted WP8 between WP7 and WP9. Once WP8 was defined, the cursor feature of the DAAS was used to move it to the left several miles to avoid a simulated storm cell that could be shown on the EHSI, assuming a radar system had been included as part of the DAAS.

At WP9 the vertical-navigation feature of the autopilot was demonstrated by making a coupled VNAV approach for a landing at Moffett Field. Except for the takeoff and landing, the DAAS provided all of the steering commands for the entire flight, and for most of the flight the autopilot flew the aircraft while the evaluation pilot monitored the flight on the map display and reviewed the aircraft status using the IDCC. After landing and before power-down, the reconfiguration feature was demonstrated by inducing a failure in the navigation/flight-planning processor.

Approximately 20% of the flights were conducted under instrument meteorological conditions and the flight scenario was changed after takeoff to comply with the ATC request. The procedures for such contingencies were not covered during the briefings; however, with little prompting from the NASA safety pilot, the evaluation pilot was able to use the DAAS flexibility to compute, display, and couple the autopilot to the revised flight plan. The pilot experience of 47 of the pilots who noted their flight time is shown in Fig. 3.

Questionnaire Results

The questionnaire contained seven questions, designed to allow either a simple response, such as yes or no, good or bad, or a lengthy comment. Although there were a number of unique responses to every question, response groups were selected using representative adjectives that best characterized the group response. The responses are ordered by degree of agreement with the question.

Figure 4 shows the response to the first question, *Do you feel the DAAS concept represents the direction in which future guidance, navigation, and flight management systems will evolve?* The results indicate that over 90% of the respondents thought that the DAAS concept or something similar is the direction in which future general-aviation avionics systems will develop. Three subjects were concerned about the cost.

Figure 5 shows the response to the second question, *Do you feel that with adequate training the DAAS system would be simpler or less complex to use than the conventional suite of avionics for IFR flight?* Nearly half of the subjects responded with "simpler" because some particular feature, such as radio auto tune or the map display, was primarily responsible. About 9% had concerns about training requirements. Twelve percent thought the system would be simpler as long as there were no ATC route changes. Over 20% felt that it would be more complex because of the greater amount of information and modes available to the pilot.

Figure 6 shows the response to the third question, *Do you feel that the functional capability provided by DAAS could enhance safety?* About 40% of the subjects responded "yes" because of

certain features such as the map, the weight and balance function, the check lists, or the performance and flight-status functions. Over 50% thought adequate training was a prerequisite. Two subjects were neutral, feeling that the added complexity may override the other system advantages. One subject felt that avionics systems were not responsible for most accidents and therefore would have a minimal impact on safety.

Figure 7 shows the response to the fourth question, *Do you feel that the functional capability provided by DAAS would reduce pilot workload in high-density IFR conditions?* About 65% of the subjects responded "yes" and indicated the feature that in their opinion reduced the workload. Typical were the map, the flight-status, and the flight-warning functions. About 19% responded yes, provided there were no ATC route changes. Five subjects felt the added capability may be offset by the complexity, and another 5 subjects responded no, either because the configuration was cumbersome or because the existing avionics have been optimized for the present ATC system.

Figure 8 shows the response to the fifth question, *Do you feel that manual entry of the NAVAID [navigational aid] data is acceptable or is a prestored data base required?* Nearly half (40%) of the responses indicated that it was acceptable but qualified their response with either the requirement for more NAVAID or WP storage or for short flights only. About 55% felt that a prestored data base is required.

The next nine figures (Figs. 9a–9i) show the response to the sixth question, which lists various elements of the DAAS. Question 6a (Fig. 9a) was, *What comments do you have regarding the electronic horizontal situation indicator (EHSI)?* Nearly 40% gave it an unqualified great or very good whereas 44% felt it was good but needed improvements such as color, better ILS presentation, different map scales, etc. Ten percent would like to control the display format, for example, with a declutter mode.

Figure 9b shows the response to question 6b, *What comments do you have regarding the Integrated Data Control Center (IDCC)?* Seventy-three percent felt that it was good, but that it needed some improvements. Some suggested more human engineering, such as, "needs better tactile feel on buttons," "color might help," "reduce parallax," etc. Three subjects specifically suggested voice input while 2 subjects felt rotary switches would be better than pushbuttons. One subject felt there were far too many buttons.

Figure 9c shows the response to question 6c, *What comments do you have regarding the autopilot functions?* Nearly 66% felt that it was excellent or good, listing some minor comment. Three subjects likened it to existing autopilots, and another three subjects felt that it was awkward to use principally because the mode-enunciation panel was remote from the mode-select keys.

Figure 9d shows the response to question 6d, *What comments do you have regarding the navigation/flight planning function?* Nearly 35% felt that it was excellent and gave the pilot an impressive capability. Nearly 43% felt that it was good but suggested changes such as dedicated-altitude preselect display, an automatic data base, etc. Four subjects felt that the function was too lengthy or required excessive keyboard entries.

Figure 9e shows the response to question 6e, *What comments do you have regarding the weight and balance computation function?* Nearly everyone who responsed felt this function was very useful.

Figure 9f shows the response to question 6f, *What comments do you have regarding the performance computation function?* Nearly 40% responded with "excellent" and commented that it was very useful. About 48% felt that the function was adequate.

Figure 9g shows the response to question 6g, *What comments do you have regarding the built-in-test (BIT) function?* Over 40% responded with excellent and indicated that BIT was needed in a digital system. Nearly 40% felt that it was "good," "complete," or "OK."

Figure 9h shows the response to question 6h, *What comments do you have regarding the checklist function?* Over 70% felt that it was very useful. Six subjects would like to customize the checklist, and one subject felt checklists were not essential.

Figure 9i shows the response to question 6i, *What comments do you have regarding the ground simulation function?* Nearly 73% responded with either "excellent" or "good." Some felt that this function should be part of the production system and might partially satisfy currency requirements for IFR flight and be cost effective. Three subjects felt the function was not required.

Figure 10 shows the response to the last question on the questionnaire, *Do you feel there are any other capabilities that should be included in a DAAS-type system to improve the overall system effectiveness?* The results were quite astounding in that in 59 questionnaires there were 75 responses with 27 different ideas. Six response groups were selected to show the results. The most popular response (15%) felt that the inclusion of weather radar on the EHSI was most desirable, while 12% felt that the automatic data base would improve system effectiveness. The next three response groups each had 4 subjects and felt that the display of pertinent traffic on the EHSI, color displays, or the inclusion of additional navigation receivers, such as LORAN, OMEGA, or GPS, could improve system effectiveness. The last response group contains over 45% of the suggested functions; however, no function was mentioned by more than three subjects.

Flight Debriefing Results

After each flight the evaluation pilot and observers (when applicable) were asked to comment on the flight and the DAAS equipment, what they liked or disliked, etc. It was felt that the spontaneous comments could reveal the strong and weak elements in the DAAS. The comments raised questions about some of the DAAS features that were not demonstrated but were obviously important for a DAAS-type system, e.g., the failure and reversion modes. After the spontaneous comments, specific questions not covered in the questionnaire were asked, such as perceived training requirements, specific map features, or perceived problem areas. All of the respondents were extremely interested and helpful.

The DAAS map presentation on the EHSI was the item most often mentioned in the debriefing session. Both pilots and observers felt that the moving map feature is desirable and was responsible for maintaining their orientation, particularly since they did not plan the flight. Some pilots felt that there was too much information on the display, although they indicated that they would like to retain it all. As a solution, a declutter mode

where the pilot could select those parameters he wanted was suggested. A second solution was to place some of the vertical-situation information on the attitude indicator (ADI) when the mechanical instrument is replaced with an electronic ADI. The map slew and return features were considered helpful, and the cursor mode that allowed WPs to be moved was extremely popular and desirable. Although the exposure to the WP-generate feature was brief, more than half of the evaluators commented favorably on the feature. Several comments were made regarding the map scales. It was felt that perhaps two more scales would be helpful, one at approximately 20 n. mi./in. and one at 100 n. mi./in. It was obvious that the mission and aircraft performance will impact the map scale and both should be considered in selecting the map scales.

Another comment made by most evaluators concerned the training requirements for integrated systems like DAAS. Some of the pilots were concerned because too much information is made available, causing them to spend excessive "head down" time monitoring the displays. Pilots may require retraining to scan the display. Others felt that some of the warning modes could be improved to alleviate this problem. Some evaluators felt that the autopilot, map display, and flight warning system made flying too simple and that the pilot who always used the system would lose his proficiency, unless special training were required. In analyzing the comments, the authors feel that most of the concerns with the system, particularly in the case where the subjects thought they were "heads down more than usual," may stem from lack of experience with the system or from the nature of the flight, which emphasized the use of many system functions within a fairly short time. This was also recognized by several subjects who made a specific point of calling it to the authors' attention. During the debriefings the subjects were asked how many hours of system operation, flight, and ground simulation they would need to feel comfortable flying a single-pilot IFR flight. Most of the subjects responded between five and ten hours.

Everyone who commented on BIT felt that it is necessary for a highly integrated system like DAAS. The comments concerning the flight status/warning system were positive and constructive, suggesting auditory alarms, the use of voice, or larger lights. One frequent comment concerned the difference in location of the warning light and the warning message. (The warning lights were located near the ADI within the normal scan, whereas the warning message was displayed on the IDCC located to the right of the normal scan. Acknowledgment of the message was accomplished by pressing the message-acknowledge button on the IDCC.) Some of the pilots commented favorably regarding the warning system while others felt that the acknowledgment of the visual alert should be made where the alert occurs.

Most of the subjects had comments on the EHSI presentation and format (Fig. 11). The wind-direction arrow located at the lower right of the display was found very helpful. The aircraft trend vector (the three dashed lines emanating from the nose of the aircraft symbol in the direction of the projected flightpath) was very controversial. Approximately half of the subjects found it extremely helpful because of the "lead" information that it provided. One of the subjects found it very useful in maintaining a holding pattern required during the flight. The other half of the subjects felt that it either contributed to display clutter or was distracting and not desirable. Those subjects who felt that it contributed to clutter wanted the option to switch the trend vector on or off, depending on the situation. Those subjects that disliked the trend vector felt that the wrap around in a turn was distracting and suggested that it be truncated by adding intelligence or by projecting a shorter distance. The authors agree with the latter comment. As configured, the trend vector projects where the aircraft will be at the end of 30, 60, and 90 sec; for this class of aircraft 90 sec is too long. A projection of 20, 40, and 60 sec would be more reasonable. Toward the end of the evaluation program a course-select arrow was added to the upper left of the display. This gives the pilot an analog representation of the course-select digital read-out and is useful in visually setting up a course intercept. All subjects who had an opportunity to use the course-select arrow felt that it was a useful addition.

The DABS or Mode S function was incorporated into the DAAS to demonstrate the use of a data-link capability and the use of shared displays. Because there was no ground facility to interact with the DABS receiver, the types of messages DABS will provide were programmed into the DAAS computer to demonstrate this feature. Examples were clearances, warning messages, and weather reports. More than half of the subjects felt that it will contribute significantly toward reducing pilot workload and enhancing safety.

Several subjects commented on the lack of automatic sequencing from one waypoint to the next (the pilot manually specifies when to change WPs) and felt that it should be mechanized like the auto-course sequence function. (Activating the DAAS auto-course sequence function provided automatic switching from the inbound to outbound course when passing over a waypoint.) Although this was considered when the DAAS was designed, this feature was dropped because there was no sound criteria for WP switching outside of the air routes due to the integrity of the VORTAC signal. The alternative of constraining the flights to the defined air routes will limit the benefit of RNAV systems. Waypoint-switching criteria suggested by the subjects include: 1) switching to the next WP and its associated navigational facility, provided the navigational aid defining the next WP is valid upon passing the current active WP; 2) switching at the designated switch points on the airways and at the mid-point for undefined RNAV routes; 3) switching to the new WP as a function of geometry and distance from the navigational aid used to define the WP. It is likely that future integrated systems will incorporate one of these features.

Another DAAS feature considered useful by several subjects was the reversion to a dead-reckoning mode when radio data dropped out. This mode preserves the map display, enunciates the loss of radio data, and displays the amount of time that the aircraft has been in a dead-reckoning mode.

The most substantive criticism concerned the cockpit layout of the autopilot mode-select panel and corresponding mode-enunciation panel. The autopilot mode-select panel is located in the console between the pilot and copilot, and the autopilot enunciation panel is under the glare shield above the altimeter (Fig. 1). Most of the subjects that commented felt that the controls and corresponding displays should be together and recommended enunciation-mode control buttons. A second criticism concerned the IDCC display (Fig. 12). Entries on any page format are designated by touching the bezel button corresponding to the line where the entry is desired. The button enunciates the desired line with a flashing entry arrow to the left of the selected line. Changes typed on the keyboard appear on the scratch pad and must be transmitted to the destination indicated by the

flashing arrow by pressing the enter key. The criticism concerned the final entry. Any interruptions in the entry procedure required scanning the display to find the entry arrow. Although the subjects liked the idea of the scratch pad (rather than typing over the old value), they found it difficult to correlate the scratch-pad value with the entry line because the entry arrow was a poor indicator. Placing the designated line and scratch pad in reverse video would probably solve the problem.

Nearly everyone thought that the DAAS ground-simulation function was useful and should be used for training and for reviewing a flight prior to takeoff. A few subjects felt that it was not practical to use an expensive aircraft as a simulator.

Conclusions

The flight-evaluation program of a fully integrated, multiprocessor DAAS installed in a Cessna 402B aircraft was conducted to demonstrate the usefulness of data-busing, distributed microprocessors, and shared electronic displays, to collect data on the pilot/system interface, and to provide information for the design of future integrated avionics systems.

Sixty-four evaluation flights were flown in which one-hundred seventeen evaluation pilots and observers representing all segments of the general-aviation community participated. Based on the results of debriefings after each flight and a questionnaire that was completed by fifty-nine subjects, the DAAS hardware and functional capability appear to be adequate to meet the program objectives. A significant majority of the pilots felt that the DAAS was representative of the way avionics systems will evolve, and that the added capability would effectively improve the safety and practicability of general-aviation operations.

Of special interest were the map display on the electronic horizontal situation indicator, the flight-status and performance functions, the data-link function, the weight and balance computation function, and the built-in simulation function. The data-link capability was considered a significant contribution toward reducing pilot workload and enhancing safety.

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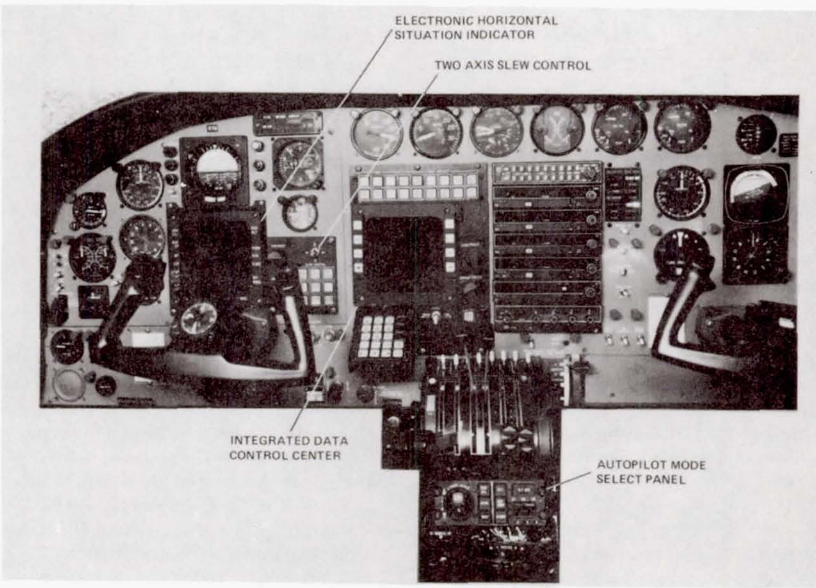


Fig. 1 DAAS instrument panel.

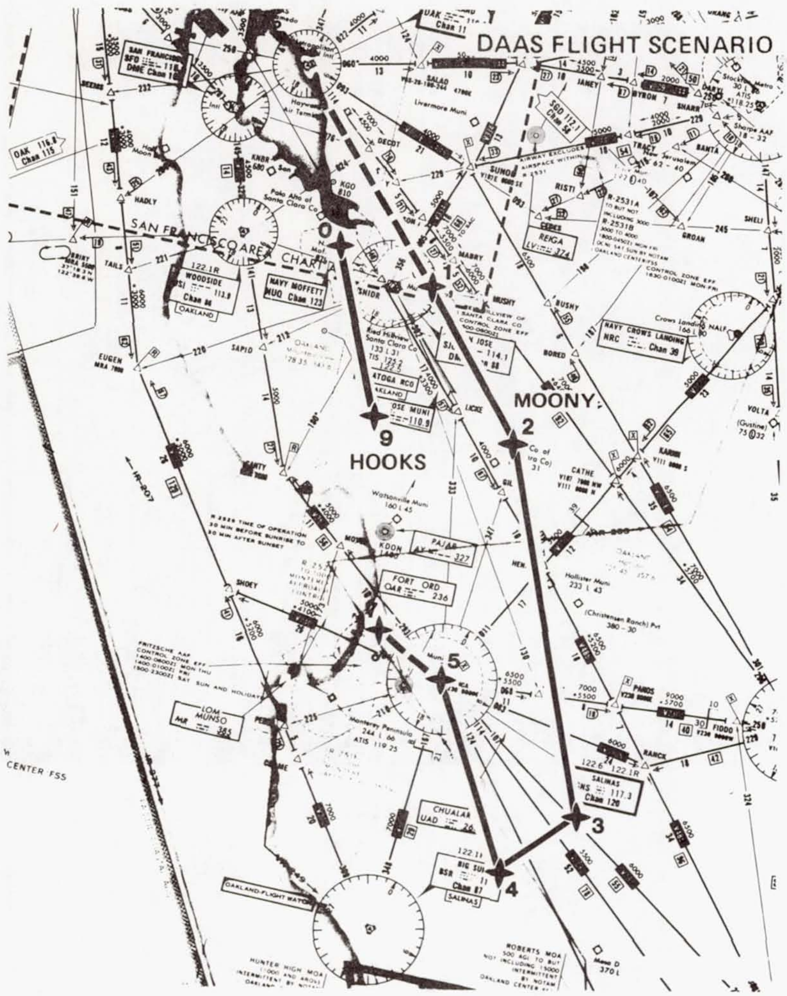


Fig. 2 DAAS flight scenario.

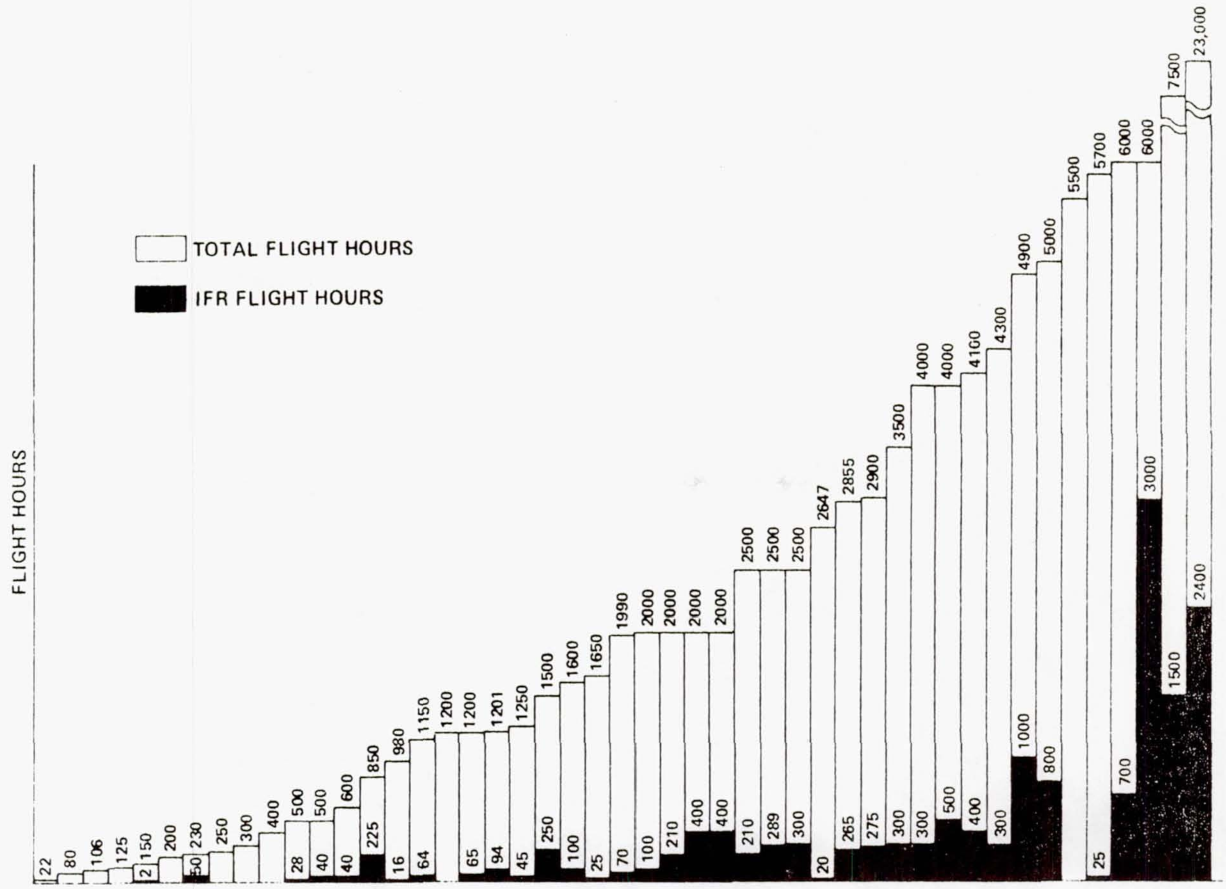


Fig. 3 Pilot flight experience.

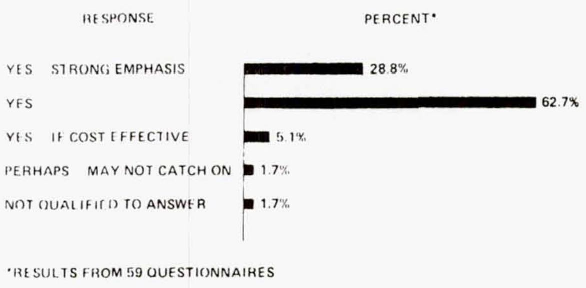


Fig. 4 Do you feel the DAAS concept represents the direction that future guidance, navigation, and flight management systems will evolve?

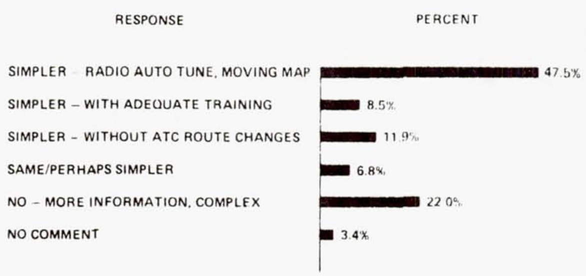


Fig. 5 Do you feel that with adequate training the DAAS system would be simpler or less complex to use than the conventional suite of avionics for IFR flight?

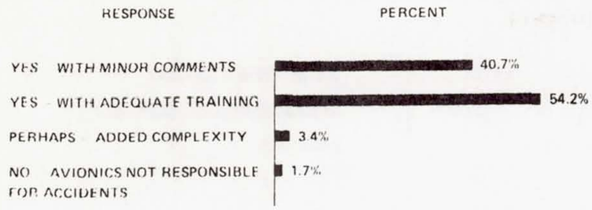


Fig. 6 Do you feel that the functional capability provided by DAAS could enhance safety?

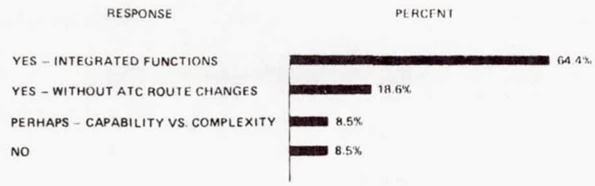


Fig. 7 Do you feel that the functional capability provided by DAAS would reduce pilot workload in high-density IFR conditions?

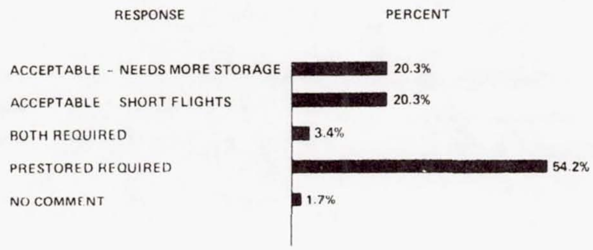
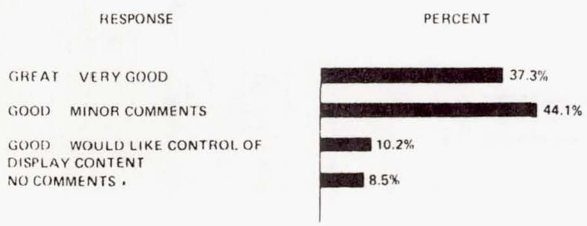
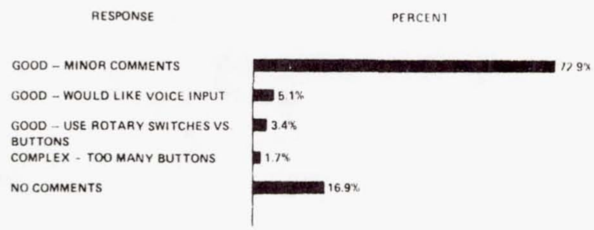


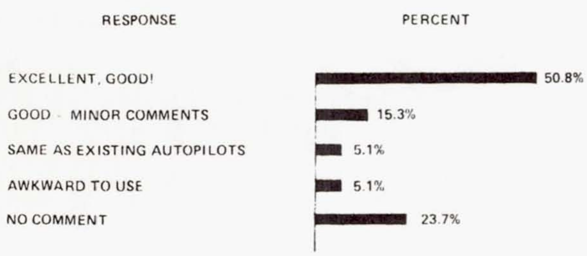
Fig. 8 Do you feel that manual entry of the NAVAID data is acceptable or is a prestored data base required?



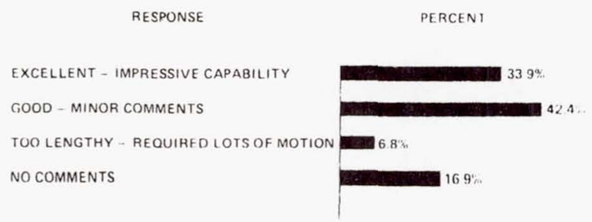
(a) What comments do you have regarding the electronic horizontal situation indicator (EHSI)?



(b) What comments do you have regarding the integrated data control center (IDCC)?

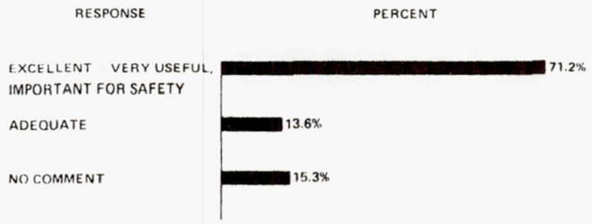


(c) What comments do you have regarding the autopilot functions?



(d) What comments do you have regarding the navigation/flight planning function?

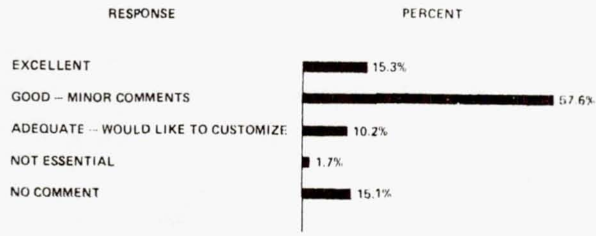
Fig. 9 Responses to questions regarding various elements of the DAAS.



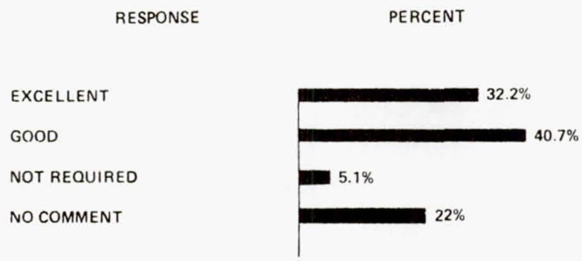
(e) What comments do you have regarding the weight and balance computation function?

(f) What comments do you have regarding the performance computation function?

(g) What comments do you have regarding the built-in-test (BIT) function?



(h) What comments do you have regarding the checklist function?



(i) What comments do you have regarding the ground simulation function?

Fig. 9 Concluded.

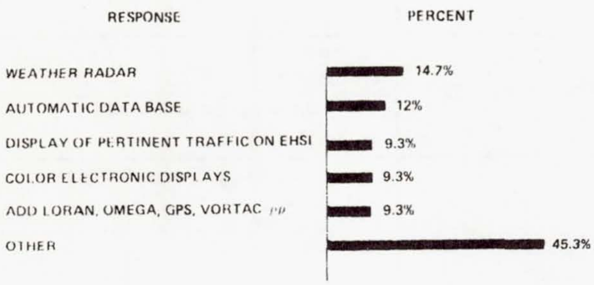


Fig. 10 Do you feel there are any other capabilities that should be included in a DAAS-type system to improve the overall system effectiveness?

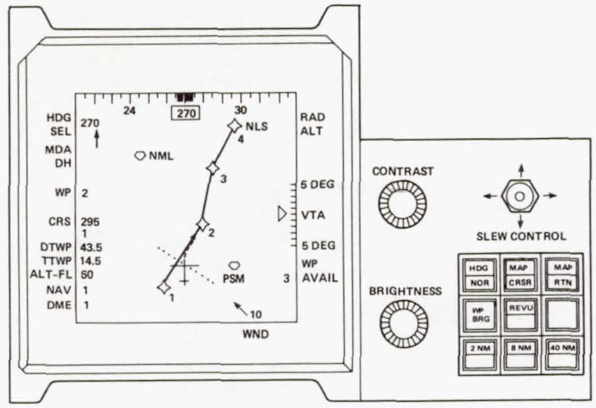


Fig. 11 Electronic horizontal situation indicator (EHSI).

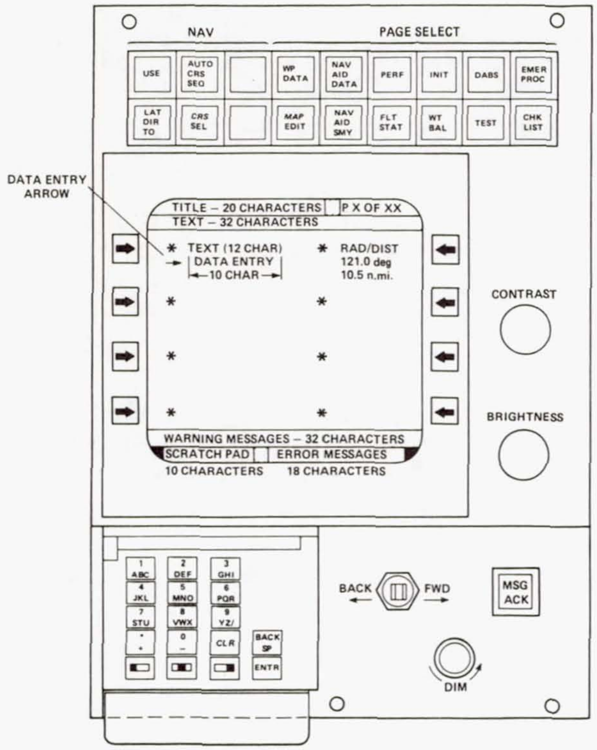


Fig. 12 Integrated data control center (IDCC).

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16. Abstract

NASA Ames Research Center has recently tested a demonstration advanced avionics system (DAAS) for general-aviation aircraft. The objective was to provide information required for the design of reliable, low-cost, advanced avionics systems which would make general-aviation operations safer and more practicable. Guest pilots flew a DAAS-equipped NASA Cessna 402-B aircraft to evaluate the usefulness of data busing, distributed microprocessors, and shared electronic displays, and to provide data on the DAAS pilot/system interface for the design of future integrated avionics systems. Evaluation results indicate that the DAAS hardware and functional capability met the program objective. Most of the pilots felt that the DAAS was representative of the way avionics systems will evolve and felt the added capability would improve the safety and practicability of general-aviation operations. This paper presents the flight-evaluation results compiled from questionnaires, summarizes the results of the debriefings, and presents the general conclusions of the flight evaluation.

17. Key Words (Suggested by Author(s))

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